CAM MECHANISM FOR LENS BARREL

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a cam mechanism for a lens barrel which is provided with a cam ring for moving a linearly guided ring member of the lens barrel.

2. Description of the Related Art

Photographing lens barrels are often provided with a cam mechanism using a cam ring wherein the cam ring is provided on an inner peripheral surface thereof with a set of cam grooves while a set of cam followers which are respectively engaged in the set of cam grooves are formed on a linearly guided ring member which is linearly guided along a photographing optical axis so that the linearly guided ring member moves between a ready-to-photograph position and an accommodation position (retracted position). Therefore, each cam groove of the cam ring has a photographing section for moving the linearly guided ring member to the ready-to-photograph position and an accommodation section for positioning the linearly guided ring member to the accommodation position, in which no pictures are taken.

Such cam grooves of the cam mechanism are conventionally formed on the cam ring so that the opposite

ends of each cam groove are formed as closed ends, i.e., so that either end of each cam groove is not open at the front end or the rear end of the cam ring. Even in the case where each cam groove is provided at the front end or the rear end of the cam ring with a cam follower insertion opening through which the associated cam follower is inserted into the cam groove, each of the aforementioned photographing section and the aforementioned accommodation section is shaped so that both the opposite ends thereof are closed (i.e., so that each of the front cam surface and the rear cam surface in each cam groove can be in contact with the associated cam follower).

However, the inventors of the present invention have found that the above described conventional cam groove design, which forms each cam groove as a closed cam groove, restricts the reduction in axial length of the cam ring, thus preventing the length of the lens barrel from being minimized.

SUMMARY OF THE INVENTION

The present invention provides a cam mechanism for a lens barrel which allows a further reduction in length of a cam ring of the lens barrel, to thereby allow a further reduction in length of the lens barrel when the lens barrel is in the accommodation position.

According to an aspect of the present invention, a cam mechanism for a lens barrel is provided, including an annular member which is linearly guided along an optical axis, the annular member having at least one cam follower on an outer peripheral surface thereof; a cam ring having at least one cam groove on an inner peripheral surface thereof, the cam groove including a photographing section for moving the annular member to a ready-to-photograph position thereof, and an accommodation section for positioning the annular member to an accommodation position thereof at which no photographing operation is performed, the cam follower being engaged in the cam groove; and a biasing device for biasing the annular member forward to normally press the cam follower against a front cam surface in the cam groove. A rear end portion of the cam groove is open at a rear end surface of the cam ring to serve as the accommodation section, and the cam follower is disengageable from the front cam surface in the cam groove against a biasing force of the biasing device when the cam follower is engaged in the accommodation section.

According to this structure, the annular member (cam follower) can be made to move rearward against the spring force of the spring device when engaged in the accommodation section of the cam groove since the opened rear end portion of the cam groove is formed to serve as

the accommodation section of the cam groove. This structure makes it possible to shorten the axial length of the cam ring, which in turn makes it possible to shorten the length of the lens barrel.

It is desirable for the cam mechanism to further include a linear guide ring which is linearly guided along the optical axis and positioned inside the cam ring. The cam ring can include a circumferential groove formed on an inner peripheral surface of the cam ring in the vicinity of a rear end thereof. The linear guide ring can include an outer flange which is formed on an outer peripheral surface of the linear guide ring to be engaged in the circumferential groove in a manner so that a relative rotation between the outer flange and the circumferential groove about the optical axis is possible and so that the outer flange and the circumferential groove are prevented from moving relative to each other along the optical axis. It is desirable for the accommodation section to overlap the circumferential groove. The outer flange can include at least one cut-out portion which allows the cam follower to enter the cut-out portion when the annular member is in the accommodation position.

It is desirable for the lens barrel to include a photographing optical system including an optical member supported by the annular member. The optical member can

include at least one intermediate lens group of the photographing optical system. It is desirable for a lens frame of a front lens group of the photographing optical system which is positioned in front of the intermediate lens group be in contact with the annular member when the annular member is in the accommodation position.

The biasing device can be a coil spring positioned between the annular member and a lens frame of a rear lens group of the photographing optical system which is positioned behind the intermediate lens group.

It is desirable for the lens frame of the rear lens group to be in contact with a light shield plate provided in the lens barrel by spring force of the coil spring when the annular member is in the accommodation position.

It is desirable for the lens barrel to be a zoom lens barrel, and for the photographing section to be formed so as to move the annular member to a ready-to-photograph position thereof among a plurality of ready-to-photograph positions corresponding to a plurality of different focal lengths.

It is desirable for the accommodation section to be elongated in a circumferential direction of the cam ring.

The optical member, which is supported by the annular member, can include a shutter unit which is fixed to the annular member.

The annular member can include a ring portion with a center thereof on the optical axis; and at least one guide arm which projects rearward from the ring portion to be linearly guided along the optical axis, wherein the cam follower extends radially outwards from the guide arm.

The lens barrel can be a telescoping type zoom lens barrel having a plurality of external telescoping barrels, the light shield plate being fixed to a rear end of an outermost external telescoping barrel of the plurality of external telescoping barrels.

In another embodiment, a cam mechanism for a lens barrel is provided, including an annular member which holds at least one lens group at a center of the annular member, and is linearly guided along an optical axis, the annular member including at least one cam follower; and a cam ring positioned coaxially with the annular member and having at least one cam groove, wherein rotation of the cam ring causes the annular member to move along the optical axis due to engagement of the cam groove with the cam follower formed on the annular member. It is desirable for the cam groove to include a photographing section for moving the annular member to a ready-to-photograph position thereof, and an accommodation section for positioning the annular member to a retracted position positioned behind the ready-to-photograph position in the optical axis direction.

It is desirable for a rear end portion of the cam groove to be open at a rear end surface of the cam ring to be formed as the accommodation section. It is desirable for the cam follower to be normally pressed against a front cam surface in the cam groove by a biasing device. The cam follower is disengageable from the front cam surface in the cam groove against the spring force of the biasing device when engaged in the retracting section.

The present disclosure relates to subject matter contained in Japanese Patent Application No.2002-359802 (filed on December 11, 2002) which is expressly incorporated herein by reference in its entirety.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be discussed below in detail with reference to the accompanying drawings, in which:

Figure 1 is a diagram showing lens-group-moving paths of a step-zoom lens system (which includes a switching lens group) of a zoom lens barrel according to the present invention;

Figure 2 is an exploded perspective view of an embodiment of the zoom lens barrel according to the present invention;

Figure 3 is a longitudinal cross sectional view of the zoom lens barrel shown in Figure 2 in the retracted

state, showing only an upper half of the zoom lens barrel from an optical axis;

Figure 4 is a longitudinal cross sectional view of the zoom lens barrel shown in Figure 2 at the wide-angle extremity which is focused on an image at infinity, showing only an upper half of the zoom lens barrel from the optical axis;

Figure 5 is a longitudinal cross sectional view of the zoom lens barrel shown in Figure 2 at telephoto extremity which is focused on an image at infinity, showing only an upper half of the zoom lens barrel from the optical axis;

Figure 6 is a developed view of an inner peripheral surface of a cam ring of the zoom lens barrel shown in Figure 2;

Figure 7 is a developed view of an inner peripheral surface of a switching ring of the zoom lens barrel shown in Figure 2;

Figure 8 is a longitudinal cross sectional view of a portion of the zoom lens barrel shown in Figure 2, showing a structure of engagement of a first lens group support ring with a fourth lens frame, showing only an upper half of the portion of the zoom lens barrel from the optical axis;

Figure 9 is a developed perspective view of the

switching ring, the first lens group support ring and a first linear guide ring of the zoom lens shown in Figure 2;

Figure 10 is a perspective view of a second/third lens group support unit of the zoom lens barrel shown in Figure 2;

Figure 11 is an exploded perspective view of the second/third lens group support unit shown in Figure 10;

Figure 12 is a longitudinal cross sectional view of a switching mechanism of the zoom lens barrel shown in Figure 2 that includes the second/third lens group support unit shown in Figure 10, showing only an upper half of the switching mechanism from the optical axis;

Figure 13 is a perspective view of an overtravel mechanism incorporated in the second/third lens group support unit shown in Figures 10 and 11;

Figure 14 is a developed view of the second/third lens group support unit in a wide-angle mode;

Figure 15 is a developed view of the second/third lens group support unit in a telephoto mode;

Figure 16 is a front elevational view of the second/third lens group support unit in a state shown in Figure 14;

Figure 17 is a front elevational view of the second/third lens group support unit in a state shown in

Figure 15;

Figures 18A through 18D are developed views of the switching ring shown in Figure 7, the first linear guide ring shown in Figure 9 and a switching leaf of the second/third lens group support unit shown in Figure 11 in different states, showing transitions in relative position among these three elements of the zoom lens barrel from a state at wide-angle extremity shown in Figure 18A to a state at telephoto extremity shown in Figure 18D; and

Figure 19 is a developed view of a cam groove provided on a cam ring of the zoom lens barrel.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Figure 1 shows a zoom lens system provided in an embodiment of a zoom lens barrel according to the present invention. The zoom lens system of the zoom lens barrel 10 includes a positive first lens group L1, and a negative second lens group L2, a positive third lens group L3 and a negative fourth lens group L4, in that order from the object side (left side as viewed in Figure 3). The second lens group L2 and the third lens group L3 serve as a distance-varying lens group (L23) which changes the distance therebetween at an intermediate range of focal length (mode switching section) from a wide distance in a wide-angle range (wide-angle mode section) to a narrow

distance in a telephoto range (telephoto mode section) and vice versa. The second lens group L2 and the third lens group L3 move together without changing the distance therebetween in each of the wide-angle range and the telephoto range. The first lens group L1 and the fourth lens group L4 always move together without changing the distance therebetween. Over the entire zooming range from the short focal length extremity (wide-angle extremity (W)) to the long focal length extremity (telephoto extremity (T)), each of the first lens group L1, the distance-varying lens group L23 and the fourth lens group L4 moves monotonously in a forward direction from the image side (right side as viewed in Figure 1) to the object side (left side as viewed in Figure 1) when a zooming operation is carried out from wide-angle extremity to telephoto extremity, or in a retracting direction from the object side to the image side (from left to right as viewed in Figure 1) when a zooming operation is carried out from telephoto extremity to wide-angle extremity. The present embodiment of the zoom lens barrel 10 is a step-zoom lens barrel which changes the focal length stepwise (specifically, six different focal lengths) when performing a zooming operation, and the distance-varying lens group L23 serves as a focusing lens group in the step-zoom lens barrel. Accordingly, solid lines shown in

Figure 1 which are drawn in association with the first lens group L1, the distance-varying lens group L23 and the fourth lens group L4, represent associated cam diagrams (which include cam diagrams for a focusing operation). A reference moving path of the distance-varying lens group L23 to perform a zooming operation for an image at infinity is represented by one-dot chain lines shown in Figure 1 which are drawn in association with the distance-varying lens group L23.

This type of zoom lens system having a distance-varying lens group in which the distance between two lens elements varies at an intermediate focal length has been proposed in U.S.P.No.6, 369,955 (Japanese Unexamined Patent Publication No.2000-275518), the assignee of which is the same as that of the present invention. This zoom lens system includes a plurality of movable lens groups which are moved to vary the focal length of the zoom lens system, and at least one lens group of the plurality of movable lens groups includes two sub-lens groups serving as a switching lens group. One of the two sub-lens groups is moveable, along the optical axis of the zoom lens system, to be selectively positioned at one of the movement extremities of the moveable sub-lens group with respect to the other sub-lens group. In a short-focal-length side zooming range covering the short focal length extremity

over an intermediate focal length, the moveable sub-lens group is arranged to position at one of the movement extremities thereof. In a long-focal-length side zooming range covering the long focal length extremity over the intermediate focal length, the moveable sub-lens group is arranged to position at the other of the movement extremities thereof. The moving path of the switching lens group having the two sub-lens groups, and the moving paths of the other lens groups of the plurality of movable lens groups are discontinued at the intermediate focal length. The zoom lens system is arranged to form an image on a predetermined image plane in accordance with a position of the moveable sub-lens group. Although the first through fourth lens groups L1 through L4 are shown as a single lens elements in the lens-group-moving paths shown in Figure 1, each of the first through fourth lens groups L1 through L4 generally consists of more than one lens element.

Figures 2 through 19 show the overall structure of the present embodiment of the zoom lens barrel 10. The zoom lens barrel 10 is provided with a stationary barrel 11 which is fixed to a camera body. As shown in Figures 2 through 5, the stationary barrel 11 is provided on an inner peripheral surface thereof with a female helicoid 11a and a plurality of linear guide grooves 11b (only one

of them appears in Figure 2) which extend parallel to an optical axis O. As can be understood from Figures 3 through 5, the zoom lens barrel 10 is a telescoping type zoom lens which is provided with three external telescoping barrels: a first external barrel (helicoid ring) 12, a second external barrel (cam ring) 15 and a third external barrel (switching ring) 16, which are concentrically arranged about the optical axis O. The female helicoid 11a of the stationary barrel 11 is engaged with a male helicoid 12a which is formed on an outer peripheral surface of the helicoid ring 12 in the vicinity of the rear end thereof. The zoom lens barrel 10 is provided with a second linear guide ring 13 which is fitted in the helicoid ring 12 to be movable together with the helicoid ring 12 along the optical axis O and to be freely rotatable relative to the helicoid ring 12. Namely, the helicoid ring 12 is provided on an inner peripheral surface thereof with two circumferential grooves 12c which extend parallel to each other in a circumferential direction of the helicoid ring 12, while the second linear guide ring 13 is provided on an outer peripheral surface thereof with a pair of guide projections 13a which are respectively engaged in the two circumferential grooves 12c of the helicoid ring 12 to be freely movable therein. The pair of guide projections 13a, which are aligned in a direction parallel to the optical

axis O as shown in Figure 2, remain respectively engaged with the two circumferential grooves 12c when the zoom lens barrel 10 is in use. The second linear guide ring 13 is provided at the rear end thereof with a plurality of radial projections 13b (only one of them appear in Figure 2) which extend radially outwards to be engaged in the plurality of linear guide grooves 11b of the stationary barrel 11, respectively.

The helicoid ring 12 is provided on the thread of the male helicoid 12a with a spur gear 12b which is engaged with a drive pinion 14. The drive pinion 14 is provided in a recessed portion 11c (see Figure 2) formed on an inner peripheral surface of the stationary barrel 11. The drive pinion 14 is supported by the stationary barrel 11 to be freely rotatable in the recessed portion 11c on an axis of the drive pinion 14. Accordingly, forward and reverse rotations of the drive pinion 14 cause the helicoid ring 12 to move forward rearward along the optical axis O while rotating about the optical axis O, thus causing the second linear guide ring 13 to move linearly along the optical axis O along with the helicoid ring 12.

The cam ring 15 is fitted inside the second linear guide ring 13. Figure 6 is a developed view of an inner peripheral surface of the cam ring 15. The cam ring 15 is provided, on an outer peripheral surface thereof in the

vicinity of the rear end of the cam ring 15, with a guide pin 15b which extends radially outwards from a portion of the male helicoid 15a. The male helicoid 15a is engaged with a female helicoid 13c formed on an inner peripheral surface of the second linear guide ring 13, while the guide pin 15b is engaged in a clearance slot 13d which is formed on the second linear guide ring 13 to extend in a direction both in a circumferential direction of the second linear guide ring 13 and in the optical axis direction (the direction of the optical axis O). The guide pin 15b passes through the clearance slot 13d to be engaged in a linear guide groove 12d, which is formed on an inner peripheral surface of the helicoid ring 12d (shown by broken lines in Figure 2) and extends parallel to the optical axis O. Therefore, a rotation of the helicoid ring 12 causes the cam ring 15 to move along the optical axis O while rotating about the optical axis O due to the engagement of the female helicoid 13c with the male helicoid 15a. The cam ring 15 is provided on an inner peripheral surface thereof with a female helicoid 15c (see Figures 2 and 6) and a set of three bottomed cam grooves 15d (only one of them is shown in Figure 19).

The zoom lens barrel 10 is provided inside the cam ring 15 with three concentric rings: the switching ring 16, a first lens group support ring 17 and a first linear

guide ring 18, which fit inside each other in that order in a radially inward direction. The first lens group support ring 17 supports the first lens group L1. Figure 7 is a developed view of the switching ring 16. The switching ring 16 and the first lens group support ring 17 move together along the optical axis O while the switching ring 16 is allowed to rotate freely about the optical axis O relative to the first lens group support ring 17. The first lens group support ring 17 is provided, on an outer peripheral surface thereof in the vicinity of the rear end of the first lens group support ring 17, with a male helicoid 17a, and is further provided immediately in front of the male helicoid 17a with a guide projection 17b. The guide projection 17b is engaged in a circumferential groove 16a (see Figure 7) which is formed on an inner peripheral surface of the switching ring 16 in the vicinity of the rear end thereof to allow a relative rotation between the guide projection 17b and the circumferential groove 16a about the optical axis O.

The male helicoid 17a of the first lens group support ring 17 is engaged with the female helicoid 15c of the cam ring 15. The cam ring 15 is provided on an inner peripheral surface thereof with a set of six rotation transfer grooves 15e (only three of them appear in Figure 2) which extend parallel to the optical axis O, while the

switching ring 16 is provided, on an outer peripheral surface thereof in the vicinity of the rear end of the switching ring 16, with a set of six rotation transfer projections 16b (only three of them appear in Figure 2) which project radially outwards to be engaged in the set of six rotation transfer grooves 15e, respectively.

On the other hand, the second linear guide ring 13 is provided on an inner peripheral surface thereof with a plurality of linear guide grooves 13e (only one of them appears in Figure 2) which extend parallel to the optical axis O, while the first linear guide ring 18 is provided, on an outer peripheral surface thereof in the vicinity of the rear end of the first linear guide ring 18, with a plurality of guide projections 18a (only two of them appear in Figure 9) which project radially outwards to be engaged in the plurality of linear guide grooves 13e, respectively. The first linear guide ring 18 is provided on an outer peripheral surface thereof with a linear guide groove 18b (see Figure 9) which extend parallel to the optical axis O, while the first lens group support ring 17 is provided, on an inner peripheral surface thereof in the vicinity of the rear end of the first lens group support ring 17, with a linear guide projection 17c which projects radially inwards to be engaged in the linear guide groove 18b (see Figure 9). Therefore, each of the second linear guide ring

13, the first linear guide ring 18 and the first lens group support ring 17 is movable along the optical axis O without relatively rotating about the optical axis O. The first linear guide ring 18 is provided in the immediate vicinity of the rear end thereof with an outer flange 18f (see Figure 9) which projects radially outwards to be engaged in a circumferential groove 15f (see Figure 6) which is formed on an inner peripheral surface of the cam ring 15 in the immediate vicinity of the rear end thereof so that a relative rotation between the outer flange 18f and the circumferential groove 15f about the optical axis O is possible, and so that the outer flange 18f and the circumferential groove 15f move together in the optical axis direction.

Therefore, if a rotation of the cam ring 15 is transferred to the switching ring 16 via the engagement of the set of six rotation transfer projections 16b with the set of six rotation transfer grooves 15e, the first lens group support ring 17, which has the male helicoid 17a engaged with the male helicoid 15c of the cam ring 15 and is prevented from rotating by the first linear guide ring 18, moves along the optical axis O.

The zoom lens barrel 10 is provided in the rear of the first lens group support ring 17 with a fourth lens group support ring 19. The fourth lens group support ring

19 is supported by the first lens group support ring 17 to be freely movable linearly along the optical axis O without rotating about the optical axis O relative to the first lens group support ring 17. The fourth lens group support ring 19 supports the fourth lens group L4, and is provided on an outer peripheral surface thereof with a set of three axial arms 19a which extend parallel to the optical axis O. The first lens group support ring 17 is provided with a set of three linear guide slots 17d which extend parallel to the optical axis O. The fourth lens group support ring 19 and the first lens group support ring 17 are engaged with each other with the set of three axial arms 19a being slidably engaged in the set of three linear guide slots 17d, respectively.

The zoom lens barrel 10 is provided in association with the first linear guide ring 18 with a second/third lens group support unit (ring member) 20 (see Figures 10 and 11) which supports the second lens group L2 and the third lens group L3. The second/third lens group support unit 20 is provided on a second/third lens group moving ring 21 thereof with a set of three guide arms 20a which extend parallel to the optical axis O. The first linear guide ring 18 is provided with a set of three linear guide slots 18c in which the set of three guide arms 20a are slidably engaged. A set of three cam followers 20b are

fixed to the set of three guide arms 20a in the vicinity of the rear ends thereof, respectively. Each cam follower 20b projects radially outwards to be engaged in the associated one of the three bottomed cam grooves 15d of the cam ring 15. Figure 10 shows the second/third lens group support unit 20 in an assembled state, while Figure 11 shows the second/third lens group support unit 20 in a disassembled state. As shown in Figures 6 and 19, each of the three bottomed cam grooves 15d consists of a photographing section 15d1 (which includes the wide-angle mode section, the mode switching section and the telephoto mode section which are shown in Figure 19) for moving the second/third lens group support unit 20 to a ready-to-photograph position among a plurality of ready-to-photograph positions, an accommodation section 15d2 for positioning the second/third lens group support unit 20 to an accommodation position thereof (in which no photographing operation is performed), and a transfer section 15d3, which is positioned between the photographing section 15d1 and the accommodation section 15d2, for moving the second/third lens group support unit 20 between the photographing section 15d1 and the accommodation section 15d2. The entire portion of the photographing section 15d1 and the entire portion of the transfer section 15d3 except for an end portion (rear end

portion) of the transfer section 15d3 in the vicinity of the accommodation section 15d2 are formed as narrow-width cam portions in which the associated cam follower 20b is engaged with a minimum clearance. The accommodation section 15d2 and the aforementioned rear end portion of the transfer section 15d3 are formed as open cam portions which are open at a rear end surface of the cam ring 15. Accordingly, a rotation of the cam ring 15 causes the second/third lens group support unit 20 to move linearly along the optical axis O in accordance with the contours of the set of three cam grooves 15d. The outer flange 18f of the first linear guide ring 18, which is engaged in the circumferential groove 15f of the cam ring 15 so that a relative rotation between the outer flange 18f and the circumferential groove 15f about the optical axis O is possible, is provided with a set of three cut-out portions 18f′. The set of three cut-out portions 18f′ are positioned behind the accommodation sections 15d2 of the set of three cam grooves 15 to allow the set of three cam followers 20b to enter the set of three cut-out portions 18f′ (see Figures 3, 9 and 18A; only two of them appear in Figure 9), respectively, so that each cam follower 20b can move rearward beyond the front end surface of the outer flange 18f when the second/third lens group support unit 20 retracts to its retracted position (accommodation

position).

The zoom lens barrel 10 is provided between the second/third lens group support unit 20 and the fourth lens group support ring 19 with a compression coil spring (biasing device) 31 for biasing the fourth lens group support ring 19 rearward. Each of the set of three axial arms 19a is provided with a claw portion 19b (see Figure 8) which is engaged with an associated inward projection 17e (see Figures 8 and 9) which is formed on the first lens group support ring 17 at the rear end thereof to determine the rear limit for the axial movement of the fourth lens group support ring 19 with respect to the first lens group support ring 17 against the spring force of the compression coil spring 31 to prevent the fourth lens group support ring 19 from coming out of the first lens group support ring 17. The fourth lens group support ring 19 remains at its rearmost position with respect to the first lens group support ring 17 in a ready-to-photograph state of the zoom lens barrel 10.

Operations of the above described portions of the zoom lens barrel 10 will be hereinafter discussed before the structure of the second/third lens group support unit 20 is discussed in detail. Rotating the helicoid ring 12 by rotation of the drive pinion 14 causes the helicoid ring 12 to move along the optical axis O while rotating about

the optical axis O, thus causing the second linear guide ring 13, which is prevented from rotating, to move along the optical axis O together with the helicoid ring 12. This rotation of the helicoid ring 12 is transferred to the cam ring 15 to move the cam ring 15 along the optical axis O together with the first linear guide ring 18, which is linearly guided, while rotating about the optical axis O. At the same time, this rotation of the cam ring 15 causes the switching ring 16 to move together with the first lens group support ring 17, which is linearly guided, along the optical axis while rotating about the optical axis O with respect to the first lens group support ring 17. When the first lens group support ring 17 moves forward from its retracted position shown in Figure 4, the compression coil spring 31 resiliently expands gradually to position the fourth lens group support ring 19 at its rearmost position with respect to the first lens group support ring 17. This rearmost position corresponds to wide-angle extremity in the zooming range. Thereafter the first lens group support ring 17 and the fourth lens group support ring 19 move together. Since the first lens group support ring 17 and the fourth lens group support ring 19 hold the first lens group L1 and the fourth lens group L4, respectively, the first lens group L1 and the fourth lens group L4 move together along the optical axis O to be linearly

proportional to the angle of rotation of the helicoid ring 12 (without varying the distance between the first lens group L1 and the fourth lens group L4) as shown in Figure 1.

As can be clearly seen in Figure 3, a front end surface of the second/third lens group support unit 20 is positioned very closely to or comes in contact with a rear end surface of a first lens frame 29 (by which the first lens group L1 is fixed to be supported) when the zoom lens barrel 10 is in the retracted position. The first lens frame 29 is fixed to a front end portion of the first lens group support ring 17. In the retracted state shown in Figure 3, since the rear of the accommodation section 15d2 of each cam groove 15d is open, each cam follower 20b is disengaged from a front cam surface (front cam edge) in the associated cam groove 15d to become capable of moving rearward to thereby reduce the length of the zoom lens barrel 10 in the retracted state when the second/third lens group support unit 20 is pressed rearward by the first lens frame 29 against the spring force of the compression coil spring 31. At the same time, a fourth lens frame 30, to which the fourth lens group L4 is fixed to be supported thereby, is moved rearward to the position where the fourth lens frame 30 contacts with a light shield plate 35 (see Figure 3) by the spring force of the compression coil spring

31. The fourth lens frame 30 is fixed to the fourth lens group support ring 19, while the light shield plate 35 is fixed to a rear end surface of the helicoid ring 12.

On the other hand, the axial position of the second/third lens group support unit 20 is determined by the set of three bottomed cam grooves 15d, which are formed on an inner peripheral surface of the cam ring 15. The second/third lens group support unit 20 supports the second lens group L2 and the third lens group L3, while a continuous rotation of the cam ring 15 together with the switching ring 16 provides the second lens group L2 and the third lens group L3 respective moving paths thereof shown in Figure 1. The structure of the second/third lens group support unit 20, and associated structures of the cam ring 15 and the switching ring 16 will be hereinafter discussed in detail with reference to Figures 9 through 18D.

The set of three guide arms 20a are formed on the second/third lens group moving ring 21 of the second/third lens group support unit 20, while the set of three cam followers 20b are fixed to the set of three guide arms 20a, respectively. The second/third lens group support unit 20 is provided at a front end thereof with a front-end pressing ring plate 22, and is provided between the second/third lens group moving ring 21 and the front-end

pressing ring plate 22 with the second lens frame 23, a third lens frame 24, a differential linking ring 25, a differential ring 26 and a differential spring 27 which are accommodated in the space between the second/third lens group moving ring 21 and the front-end pressing ring plate 22, in that order from the object side. The third lens group L3 is fixed to the third lens frame 24 to be supported thereby. A pair of guide pins 22a are fixed to the front-end pressing ring plate 22 to extend rearward to be parallel to the optical axis O. The second lens frame 23 is provided with a pair of guide bosses 23a which are slidably fitted on the pair of guide pins 22a, respectively. A pair of compression coil springs 22b are loosely fitted on the pair of guide pins 22a to press the second lens frame 23 rearward.

Each of the third lens frame 24, the differential linking ring 25 and the differential ring 26 is rotatable about the optical axis O. The second lens frame 23 and the third lens frame 24 have cylindrical portions so that the cylindrical portion of the third lens frame 24 is fitted on the cylindrical portion of the second lens frame 23. The second lens frame 23 is provided on an outer peripheral surface of the cylindrical portion thereof with a set of four inclined cam edges 23b (only one of them appears in Figure 11) while the third lens frame 24 is provided on

an inner peripheral surface of the cylindrical portion thereof with a set of four cam followers 24a (only two of them appears in Figure 11) which are engaged with the set of four inclined cam edges 23b, respectively. Each cam edge 23b extends linearly, and is inclined with respect to both a circumferential direction of the second lens frame 23 and the optical axis direction. The third lens frame 24 is provided on an outer peripheral surface thereof with a pair of rotation transfer projections 24b while the differential linking ring 25 is provided on an inner peripheral surface thereof with a pair of rotation transfer grooves 25a in which the pair of rotation transfer projections 24b are engaged, respectively, so that the third lens frame 24 and the differential linking ring 25 rotate together at all times. The third lens frame 24 is always pressed rearward by the spring force of the pair of compression coil springs 22b to be in pressing contact with the second/third lens group moving ring 21 to determine the position of the third lens frame 24 in the optical axis direction with respect to the second/third lens group moving ring 21. The differential ring 26 is provided on an inner peripheral surface thereof with a pair of forced-rotation transfer grooves 26a (only one of them appears in Figure 11) while the differential linking ring 25 is provided on an outer peripheral surface thereof with

a pair of forced-rotation transfer projections 25b which are engaged in the pair of forced-rotation transfer grooves 26a, respectively, with a predetermined circumferential clearance between each forced-rotation transfer projection 25b and the associated forced-rotation transfer groove 26a (see Figures 16 and 17).

The differential spring 27 is a torsion spring 27 consisting of a loop portion 27a with its center substantially on the optical axis O and a pair of engaging radial projections 27b which project radially outwards from the opposite ends of the loop portion 27a, respectively. The loop portion 27a is fitted in the differential linking ring 25 to be engaged with an inner peripheral surface thereof by friction. The differential linking ring 25 is provided with a pair of radial through holes 25c into which the pair of engaging radial projections 27b are inserted from the inside of the differential linking ring 25 to project radially outwards from an outer peripheral surface of the differential linking ring 25. The differential linking ring 25 is provided on an inner peripheral surface thereof with an inward projection 25d (see Figure 11) which is engaged with the loop portion 27a of the differential spring 27 to prevent the differential spring 27 from coming off the differential linking ring 25. The differential ring 26

is provided with a rotation transfer projection 26b which projects rearwards, and the pair of engaging radial projections 27b of the differential spring 27 are in pressing in contact with opposite surfaces of the rotation transfer projection 26b in a circumferential direction of the differential ring 26 in opposite directions towards each other. The differential linking ring 25 normally rotates together with the differential ring 26 via the differential spring 27 when the differential ring 26 rotates. However, if the differential linking ring 25 reaches one end of the range of rotation thereof (i.e., if a resistance which is generated in the differential linking ring 25 to rotate is greater than a predetermined resistance) when the differential ring 26 rotates, the differential ring 26 rotates relative to the differential linking ring 25 while the differential spring 27 is deformed to open the pair of engaging radial projections 27b (i.e., to move the pair of engaging radial projections 27b in opposite directions away from each other in a circumferential direction of the differential spring 27).

The second/third lens group support unit 20 is provided with a switching leaf 28 which is provided on an inner peripheral surface thereof with a rotation transfer groove 28a which extends parallel to the optical axis O, while the rotation transfer projection 26b is provided with

a linking pin 26c which projects radially outwards to be engaged in the rotation transfer groove 28a. As shown in Figure 9, the switching leaf 28 is positioned in a guide slot 18d (see Figure 9) formed on the first linear guide ring 18, and is supported by the first linear guide ring 18 to be movable in a circumferential direction of the first linear guide ring 18 with respect to the first linear guide ring 18 within a predetermined angle of rotation about the optical axis O. The switching ring 16 is provided on an inner peripheral surface thereof with a switching groove 16c, while the switching leaf 28 is provided, on an outer peripheral surface thereof in the vicinity of the front end of the switching leaf 28, with a follower projection 28b which is engaged in the switching groove 16c.

As shown in Figures 7 and 18A, the switching groove 16c consists of a telephoto section 16cT, a switching section 16cK and a wide-angle section 16cW, in that order from rear to front of the switching groove 16c (i.e., from bottom to top as viewed in Figure 7). Each of the telephoto section 16cT and the wide-angle section 16cW is inclined with respect to both a circumferential direction of the switching ring 16 and the optical axis direction. The lead angle of each of the telephoto section 16cT and the wide-angle section 16cW is the same as that of the threads of the female helicoid 15c of the cam ring 15, and the

direction of inclination of each of the telephoto section 16cT and the wide-angle section 16cW is opposite to that of the threads of the female helicoid 15c of the cam ring 15. The switching section 16cK extends parallel to the optical axis O. Therefore, when the cam ring 15 and the switching ring 16 rotate together, the switching leaf 28 does not rotate relative to the first linear guide ring 18 as long as the follower projection 28b of the switching leaf 28 remains engaged in either the telephoto section 16cT or the wide-angle section 16cW. This keeps the distance between the second lens group L2 and the third lens group L3 at either a wide distance in the wide-angle range or a narrow distance in the telephoto range (see Figure 1). However, in the case where the follower projection 28b of the switching leaf 28 is engaged in the switching section 16cK, the switching leaf 28 rotates relative to the first linear guide ring 18 when the cam ring 15 and the switching ring 16 rotate together. This rotation of the switching leaf 28 relative to the first linear guide ring 18 varies the distance between the narrow distance and the wide distance.

As shown in Figures 14 and 15, the third lens frame 24 is provided with a rotational range limit groove 24c and the second/third lens group moving ring 21 is provided with a stop projection 21a which is engaged in the

rotational range limit groove 24c to limit the range of rotation (rotational angle) of the third lens frame 24 relative to the second/third lens group moving ring 21 to a sufficient range for the third lens frame 24 to be switched between the wide-angle position and the telephoto position. The range of rotation (rotational angle) of a combination of the switching leaf 28 and the differential ring 26 is determined to be greater than that of the third lens frame 24, and the difference therebetween is absorbed by the differential spring 27.

If the switching leaf 28 is rotated counterclockwise from the position shown in Figure 16 to the position shown in Figure 17, via the engagement of the follower projection 28b with the switching groove 16c in a state shown in Figure 14 where the second lens frame 23 (the second lens group L2) and the third lens frame 24 (the third lens group L3) are sufficiently apart from each other in the optical axis direction, the differential ring 26 rotates. This rotation of the differential ring 26 is transferred to the differential linking ring 25 via the engagement of the pair of engaging radial projections 27b of the differential spring 27 with the rotation transfer projection 26b to rotate the third lens frame 24 in the same rotational direction as the differential ring 26. This rotation of the third lens frame 24 causes one end of the rotational

range limit groove 24c (the left end as viewed in Figures 14 and 15) to come into contact with the stop projection 21a to thereby prevent the differential linking ring 25, which rotates together with the third lens frame 24, from further rotating together with the third lens frame 24. Even after the differential linking ring 25 is prevented from rotating, the differential ring 26 continues to rotate in the same rotational direction. This overtravel of the differential ring 26 is absorbed by a resilient deformation of the differential spring 27. At the same time, the rotation of the third lens frame 24 causes the second lens frame 23, which is biased rearward by the pair of compression coil springs 22b, to move rearward due to the engagement of the set of four cam followers 24a with the set of four inclined cam edges 23b, thus causing the second lens group L2 and the third lens group L3 to approach each other (see Figures 15 and 17). The pair of forced-rotation transfer projections 25b are tightly engaged with the pair of forced-rotation transfer grooves 26a, respectively, to forcefully transfer rotation of the differential ring 26 to the differential linking ring 25 in the event of the pair of engaging radial projections 27b of the differential spring 27 being open due to a resistance in the differential linking ring 25 from rotating caused by some reason.

If the switching leaf 28 is rotated reversely, i.e.,

clockwise from the position shown in Figure 17 to the position shown in Figure 16, via the engagement of the follower projection 28b with the switching groove 16c in a state shown in Figure 15 where the second lens frame 23 (the second lens group L2) and the third lens frame 24 (the third lens group L3) are positioned closely to each other in the optical axis direction, the second lens frame 23 (the second lens group L2) and the third lens frame 24 (the third lens group L3) move apart from each other in the optical axis direction in the reverse fashion to the above described fashion. The operations of the differential ring 25, the differential linking ring 26 and the differential spring 27 are the same as those described above when the switching leaf 28 is rotated counterclockwise as viewed in Figure 16. Each inclined cam edge 23b of the second lens frame 23 is provided on opposite ends thereof with a front recess 23b1 and a rear recess 23b2 for holding the associated cam follower 24a at a telephoto mode position and a wide-angle mode position with stability, respectively. The four inclined cam edges 23b each having such structure are arranged at equi-angular intervals in a circumferential direction of the second lens frame 23 (i.e., a circumferential direction of the third lens frame 24) to ensure precision in spacing (i.e., the distance) between the second lens group L2 and the third

lens group L3 and the precision in positioning the second lens group L2 and the third lens group L3 concentrically with the optical axis O.

The zoom lens barrel 10 is provided immediately behind the second/third lens group moving ring 21 with a shutter unit 32 which is fixed to the second/third lens group moving ring 21 by set screws (see Figure 2). A flexible printed wiring board (flexible PWB) 33 for electrically connecting the shutter unit 32 to a control circuit of the camera body (not shown) extends from the shutter unit 32. The zoom lens barrel 10 is provided between an inner peripheral surface of the first lens frame 17 in the vicinity of the front end thereof and a front surface of the second/third lens group support unit 20 with a light shield bellows 34.

Operations of the zoom lens barrel 10 to achieve focus will be hereinafter discussed with reference mainly to Figure 19. In the present embodiment of the zoom lens barrel, the set of three bottomed cam grooves 15d are also used to achieve focus, i.e., a focusing operation is performed with a rotation of the cam ring 15. The step-zoom lens barrel 10 has a variable focal length of six different focal lengths: four different focal lengths (steps 1, 2, 3 and 4) in the wide-angle mode and two different focal lengths (steps 5 and 6) in the telephoto

mode. The contours of the set of three bottomed cam grooves 15d are determined so as to move the second/third lens group support unit 20 (the second lens group L2 and the third lens group L3) between a closest photographing position (N) and an infinite photographing position (∞) in the optical axis direction at each of the six different focal lengths. Specifically, each cam groove 15d includes a step-1 position for the infinite photographing position (∞), a step-1 position for the closest photographing position (N), a step-2 position for the closest photographing position (N), a step-2 position for the infinite photographing position (∞), a step-3 position for the infinite photographing position (∞), a step-3 position for the closest photographing position (N), a step-4 position for the closest photographing position (N), a step-4 position for the infinite photographing position (∞), the mode switching section, a step-5 position for the infinite photographing position (∞), a step-5 position for the closest photographing position (N), a step-6 position for the closest photographing position (N), and a step-6 position for the infinite photographing position (∞), in that order in a rotating direction of the cam ring 15. The angle of rotation (the angular position of the cam ring 15) of the cam ring 15 is controlled in accordance with information on a set focal length and

an object distance.

As shown in Figure 19, each cam groove 15d is formed so that the closest photographing positions (N) in two adjacent focal-length step positions are adjacent to each other, and the infinite photographing positions (∞) in two adjacent focal-length step positions are adjacent to each other(with the exception of the adjacent steps 4 (∞) and 5 (∞). This structure is advantageous to simplify the contour of each cam groove 15d and to shorten the length thereof.

The second/third lens group support unit 20 is an annular member which supports optical elements such as the second lens group L2, the third lens group L3 and the shutter unit 32. As described above, the second/third lens group support unit 20 has the set of three cam followers 20b that are fixed to the set of three guide arms 20a, respectively. The cam ring 15 is positioned around the second/third lens group support unit 20, and has the set of three bottomed cam grooves 15d, in which the set of three cam followers 20b are engaged, respectively (see Figure 6). The first linear guide ring 18 is provided between the cam ring 15 and the second/third lens group support unit 20, and is freely rotatable about the optical axis O relative to the cam ring 15 and movable together with the cam ring 15 along the optical axis O.

Features of the present embodiment of the zoom lens barrel 10 reside in mechanical relationship among the second/third lens group support unit 20, the cam ring 15 and the first linear guide ring 18. Such features will be hereinafter discussed with reference mainly to Figures 6 and 19. As described above, each of the three bottomed cam grooves 15d includes the photographing section 15d1 (which includes the wide-angle mode section, the mode switching section and the telephoto mode section which are shown in Figure 19) for moving the second/third lens group support unit 20 to a ready-to-photograph position among a plurality of ready-to-photograph positions, the accommodation section 15d2 for positioning the second/third lens group support unit 20 to an accommodation position thereof (in which no pictures are taken), and the transfer section 15d3 for moving the second/third lens group support unit 20 between the photographing section 15d1 and the accommodation section 15d2. The entire portion of the photographing section 15d1 and the entire portion of the transfer section 15d3 except for an end portion (rear end portion) of the transfer section 15d3 in the vicinity of the accommodation section 15d2 are formed as narrow-width cam portions in which the associated cam follower 20b is engaged with a minimum clearance, whereas the accommodation section 15d2 and the

aforementioned rear end portion of the transfer section 15d3 are formed as open cam portions which are open at a rear end surface of the cam ring 15. Accordingly, these open cam portions are formed to serve as an accommodation portion for the associated cam follower 20b.

The second/third lens group support unit 20 is biased forward by the compression coil spring 31. Therefore, each cam follower 20b is biased forward by the compression coil spring 31 to come in contact with the front cam surface (front cam edge) in the associated cam groove 15d at all times. However, even though the accommodation section 15d2 is formed as an open cam portion which is open at a rear end surface of the cam ring 15 while each cam follower 20b is disengaged from the front cam surface in the associated cam groove 15d in the retracted state shown in Figure 3, there is no problem in controlling the position of the second/third lens group support unit 20 because the position of the second/third lens group support unit 20 does not have to be controlled with precision when the set of three cam followers 20b are respectively engaged in the accommodation sections 15d2 of the set of three cam grooves 15d. On the other hand, as can be clearly seen in Figure 3, a front end surface of the second/third lens group support unit 20 (specifically, a front end surface of a second lens frame 23 of the second/third lens group support

unit 20) is positioned very closely to, or comes in contact with, a rear end surface of the first lens frame 29, to which the first lens group L1 is fixed to be supported by the first lens frame 29 when the second/third lens group support unit 20 is in the retracted position. Accordingly, if the rear of the accommodation section 15d2 of each cam groove 15d is made open, each cam follower 20b is disengaged from the front cam surface (front cam edge) in the associated cam groove 15d to become capable of moving rearward by the second/third lens group support unit 20 being pressed rearward by the first lens frame 29 against the spring force of the compression coil spring 31. This makes it possible to reduce the axial length of the cam ring 15, which in turn makes it possible to reduce the length of the zoom lens barrel 10 in the retracted state. The compression coil spring 31 presses the second/third lens group support unit 20 forward, and presses the fourth lens group support ring 19 rearward at the same time. This makes the fourth lens frame 30, to which the fourth lens group L4 is fixed, move rearward to a position where the fourth lens frame 30 comes into contact with the light shield plate 35 as shown in Figure 3 when the zoom lens barrel 10 is in the retracted state.

The accommodation section 15d2 of each cam groove 15d of the cam ring 15 overlaps the circumferential groove 15f

as shown in Figure 6. The set of three cam followers 20b may interfere with the outer flange 18f of the first linear guide ring 18, which is engaged in the circumferential groove 15f, if moving rearward with each cam follower 20b being apart from the front cam surface in the associated cam groove 15d. To prevent this problem from occurring, the set of three cut-out portions 18f′, that are positioned behind the accommodation sections 15d2 to allow the set of three cam followers 20b to enter the set of three cut-out portions 18f′ (see Figures 3, 9 and 18A), are formed on the outer flange 18f so that each cam follower 20b can move rearward beyond the front end surface of the outer flange 18f when the second/third lens group support unit 20 retracts to its retracted position. Providing the outer flange 18f with the set of three cut-out portions 18f′ is also advantageous to reduce the axial length of the cam ring 15.

As can be understood from the foregoing, according to the present invention, in a cam mechanism for a lens barrel which includes an annular member that is linearly guided along an optical axis, supporting at least one optical member, and having at least one cam follower; and a cam ring having at least one cam groove on an inner peripheral surface of the cam ring, wherein the cam follower is engaged in the cam groove, and wherein the cam

groove includes a photographing section for moving the annular member to a ready-to-photograph position thereof and an accommodation section for positioning the annular member to an accommodation position thereof at which no photographing operation is performed, a further reduction in length of the cam ring is possible and also a further reduction in length of the lens barrel in its retracted state is possible.

Obvious changes may be made in the specific embodiment of the present invention described herein, such modifications being within the spirit and scope of the invention claimed. It is indicated that all matter contained herein is illustrative and does not limit the scope of the present invention.